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Autor: Berz, Martin W. / Houdré, Romuald / Andreani, Lucio Claudio

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EXCHANGE AND POLARITON EFFECTS FOR EXCITONS IN $Al_{1-x}Ga_xAs$-GaAs QUANTUM WELLS

Martin W. Berz[a,c], Romuald Houdré[a], Lucio Claudio Andreani[b], Edgar F. Steigmeier[c], Franz-Karl Reinhart[a]

[a]: *Institut de Micro- et Optoélectronique EPFL, CH-1015 Lausanne, Switzerland*

[b]: *Institut Romand de Recherche Numérique en Physique des Matériaux (IRRMA), PHB-Ecublens, CH-1015 Lausanne, Switzerland*

[c]: *Paul Scherrer Institute Zurich (PSIZ), Badenerstrasse 569, CH-8048 Zurich, Switzerland*

The excitonic photoluminescence of quantum wells emitted from the cleaved (110) facet is studied at 4.2K. A strong anisotropy is observed compared to the emission parallel to the [001] growth axis. We show that this is due to mixing between excitons and photons which propagate parallel to the quantum well. We show theoretically that interface roughness does not prevent this emission of polariton type, provided that the elastic length of the exciton is comparable or larger than the optical wavelength in the material.

There is recent interest in the experimental and theoretical aspects of two dimensional (2D) exciton polaritons in semiconductor Quantum Wells (QW's)[1,2]. In QW's, 2D excitons are coupled to 3D photons, hence the component $k_{||}$ of the photon wavevector $\mathbf{k}_{pho}$, parallel to the growth axis, is not conserved during the interaction. Optically active excitons with a wavevector component $k_{ex,\perp}$ perpendicular to the growth axis which fulfills $k_{ex,\perp} < \omega_{ex}/c'$ can decay radiatively, $\hbar\omega_{ex}$, c' being the exciton excitation energy, the light speed in the material, respectively. Whereas optically active excitons with $k_{ex,\perp} > \omega_{ex}/c'$ are dressed by a cloud of virtual photons. They are stationary with respect to radiative decay and are called quantum well exciton polaritons.

We have investigated the 4.2K photoluminescence of single quantum wells emitted from the lateral side of the sample, i.e. the cleaved (110) facet ('polariton geometry'). These spectra are compared with the emission parallel to the growth axis [001] ('conventional geometry'). At the cleaved facet, $k_\perp$ is not conserved and the exciton polariton can be transformed into a photon outside of the crystal. Hence a strong optical anisotropy is expected between the polariton and the conventional geometry.

Such effects can only be observed experimentally if the wavevector of the exciton is a conserved quantity in the QW, i.e. if the elastic length of the exciton is sufficiently long. The elastic length in QW's available today is mainly limited by the roughness of the interface. For the QW's used in this work, a relatively smooth interface is obtained by the technique of growth interruption[3] (The QW's have been grown by molecular beam epitaxy on GaAs (001) substrates.). In such QW's, the exciton is still localized, but on a length scale as long as $\approx$ 1000Å or even longer. The extension of the exciton wavefunction is in this case comparable or larger than the optical wavelength ($\approx$ 1000Å within the material). Hence the dipole approximation for the photon emission fails. We have shown theoretically that the optical anisotropy anticipated above can be observed in this case[4]: the mixing between the excitonic state and the photon field is strong if an approximate matching exists between the separation of the nodes of the excitonic center-of-mass motion and the nodes of the photon wave.

Experimentally, we find sharp emission lines in the polariton geometry which are not seen in the conventional geometry (Fig.1). These lines are quenched at temperatures higher than 40K (Fig.2). The observation of separate sharp lines is a mesoscopic effect, which arises from the small laser spot size (diameter 5μm): the individual lines correspond to excitons localized on spacially different sites. Each of them has a slightly different energy due to alloy fluctuations and/or imperfections of the interfaces. Out of all existing excitonic states, only states with strong polariton character are seen in the polariton geometry. Hence the detection probability of an exciton depends on the

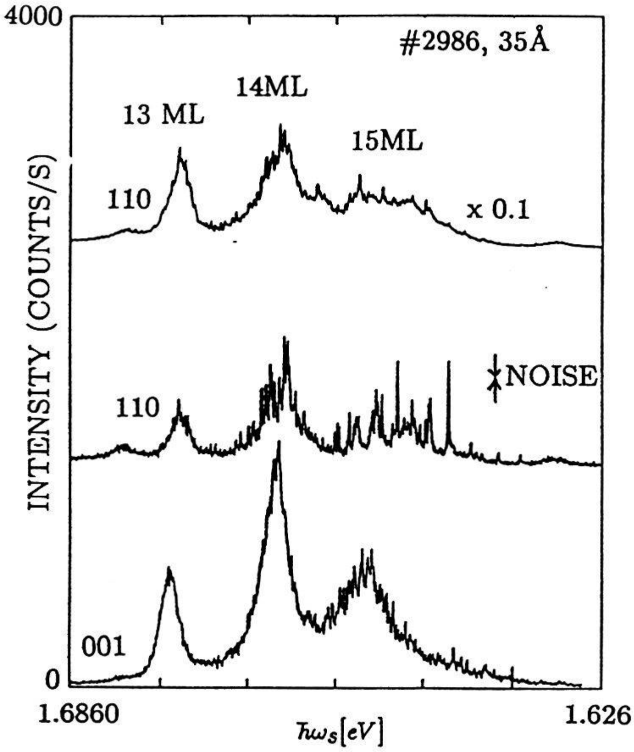

Fig.1:
Comparison between the photoluminescence emission of a 35Å well parallel to the [001] growth axis and from the cleaved (110) facet. The lower and the middle spectra have been recorded with a power density of $7W/cm^2$, $50W/cm^2$, respectively, the uppermost spectrum (×0.1) with a power density of $500W/cm^2$. The three peaks (13, 14, 15ML) of the envelope of the photoluminescence spectra correspond to monolayer (ML) fluctuations of the well width and the sharp lines are due to polariton effects.

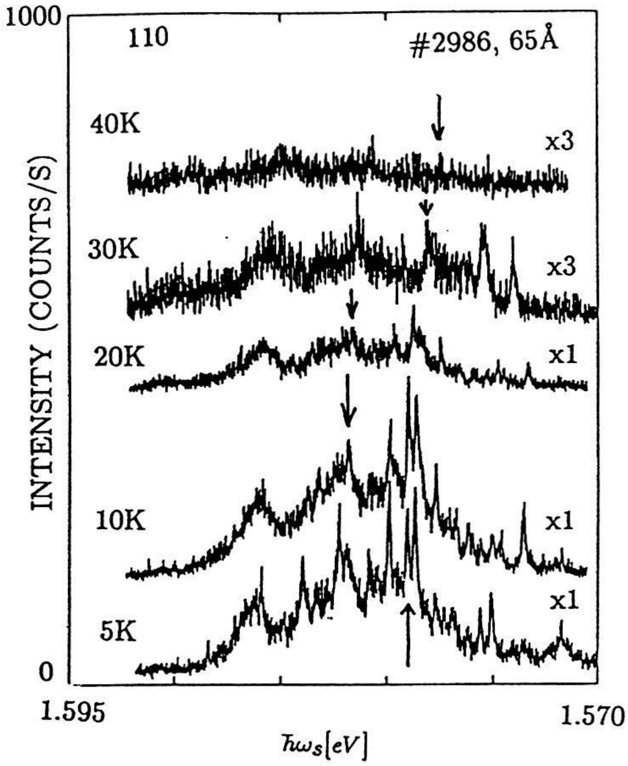

Fig.2:
Quenching of the exciton polariton mediated photoluminescence at temperatures $T > 40K$ and for a quantum well of 65Å width. Marked are some characteristic lines, which can be kept track of, passing from one temperature to the next. These emission lines are slightly shifted due to the temperature dependence of the energy gap of GaAs. The temperature is indicated at the left side.

shape of the alloy fluctuations at the site of the exciton. This is not the case in the conventional geometry, in which an average over all localized excitons is observed. The polariton emission is not seen at higher temperatures since the phase coherence of the exciton is reduced by collisions with thermally activated phonons (Fig.2). On the other hand, the photoluminescence efficiency measured in the conventional geometry does not change between 4.2K and 40K.

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